Unit 3 –Energy & States of Matter - Part 2 Objectives

1. Relate observations regarding the addition of energy by warming to increased particle motion	
2. Describe the characteristics of solids, liquids and gases in terms of particles and their: • Arrangement: use particle diagrams to account for motion and density differences; describe the process of how the arrangement of matter particles changes during phase changes. • Attractions: infer the necessity of an attractive force between particles at close range from observations of differences in cohesiveness of the three phases;	
3. Define energy; describe the ways in which it is stored in a system.	

4. Describe three ways in which energy is transferred between system and surroundings.	
5. Draw energy bar charts to account for energy storage and transfer in all sorts of changes. Make up a sample situation and sketch the bar chart.	
6. Given a heating/cooling curve for a substance, identify what phase(s) is/are present in the various portions of the curve, and what the melting and freezing temperatures for the substance are.	
7. Given a heating/cooling curve for a substance, identify which energy storage mode is changing for the various portions of the curve.	

8. Given a situation in which a substance at a given temperature undergoes a change (in temperature, phase or both), sketch a heating/cooling curve that represents the situation.	
9. State the physical meaning of the heat of fusion (H_f) and heat of vaporization (H_v) for a given substance. Use these factors to relate the mass of a substance to the energy absorbed or released during a phase change (at the melting or freezing temperature).	
10. State the physical meaning of the heat capacity (c) of a substance and use this factor to relate the mass and temperature changes to the energy absorbed or released during a change in temperature (with no phase change).	

Chemistry – Unit 3
Energy and Kinetic Molecular Theory

The story behind the difficulty we have with energy is fascinating to those of us who struggle with trying to teach energy in a coherent way, but it is long and difficult - much of it would be lost on students whose goal is to get a grip on how to use energy to describe change in the world. Nonetheless, a brief bit of background might help you understand how we are going to approach the study of energy. In the 18th and 19th centuries scientists wrestled with identifying and describing the nature of the "stuff" that produced change. One concept that became popular for a while was that of "caloric" (what we now call heat).

"Caloric was originally conceived of as a quantity that would flow from a hotter object to a cooler one that would warm up as a result. It answered the need for a way for the cause of warming to get from here to there. Not only did caloric serve as a cause for warming, it was also considered to be the cause for changes of phase. Caloric enabled particles of a substance to move farther apart until the attraction of the particles for each other became too weak to hold them together. Although Lavoisier did not think that caloric necessarily was an actual substance, in its storage and transfer it was *like* a substance.".[1]

When scientists recognized that the "stuff" involved when forces were applied to objects to lift them or change their speed was the same "stuff" that was involved when the temperature of objects changed, they worked to develop a single energy concept. "So when the energy concept was developed it was important to distinguish it from caloric. In snuffing out the caloric concept, the clear picture of energy storage and transfer that it fostered was unnecessarily lost, too."[2]
Even though we recognize that energy is not a *physical* substance, we choose to use the substance *metaphor* to describe it.

We'll use three principles to guide us in the development of the energy concept.
1. Energy can be viewed as a substance-like quantity that can be stored in a physical system.
2. Energy can "flow" or be "transferred" from one system to another and so cause changes.
3. Energy maintains its identity after being transferred.

If you are unsure what we mean by the use of a substance metaphor, consider how we describe information. We say that it can be stored in books, on computer hard drives or floppy disks or CD-ROMs. Information can be transferred from place to place via cables or by wireless transmission techniques - in fact you just did this

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[1][1] G. Swackhamer, *Cognitive Resources for Understanding Energy*, 2003, p 6
[2] G. Swackhamer, p 7

when you accessed this lesson via the Internet, transferred it to your computer and then (perhaps) printed it. But there is nothing substantial about the information itself; you can't touch it or measure its mass on a balance. The third point is important to consider because many texts talk about energy *transformations* as if somehow it is the *energy* that is changing rather than the physical system that gains or loses it. Consider the information metaphor again: even though we move information from place to place or store it in different ways, nothing about the information itself has changed.

Energy Storage and Transfer

At this point, let us consider another metaphor to describe energy storage and transfer – that of money. We store money in accounts at the bank or credit union. We can have checking accounts, various savings accounts, certificates of deposit, etc. These accounts store money. There is nothing different about the money in checking and savings accounts. This money can be transferred back and forth in the bank without changing the *nature* of the money or the *total quantity* of money that resides in the collection of accounts that is attached to your name; let's call this the system for convenience.

The same is true of energy. It is stored in objects and in the arrangement of objects in a physical system. We use different "accounts" to help us keep track of energy as its transfer causes change in the objects or in their arrangement. As with money, nothing about the energy itself has changed. Let's consider the accounts we will use in this course.

1. Thermal energy, E_{th} – energy of motion. The quantity of thermal energy stored by an object is related to both its mass and velocity. You instinctively recognize this as you would rather catch barehanded a baseball thrown by your instructor than one thrown by a major league pitcher. Similarly, you wouldn't mind if a softball landed on your toe, but would suddenly move if a shot put were heading that way.

2. Interaction energy, E_i – energy stored in the system due to the arrangement of molecules that exert attractions on one another. Attractions can result in a *decrease* in the energy of a system. As the particles become more tightly bound, their E_i is lowered. Solids possess the lowest E_i; liquids possess more E_i since the molecules in a liquid are freer to move than those in a solid; and a gas possesses the greatest amount of E_i since the molecules in a gas have completely broken free from one another. E_i is the energy account involved when phase changes occur.

3. Chemical potential energy, E_{ch}- energy due to attractions of atoms *within* molecules. These attractions are described as chemical bonds because they are directed between specific atoms in the molecule.

There are three energy transfer modes and these are described as gerunds to emphasize that they are *processes* rather than real things apart from energy. They

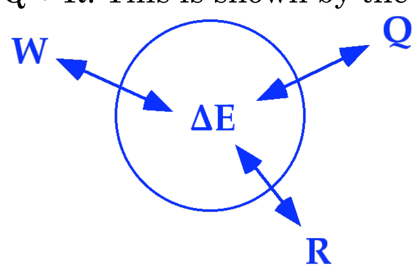
are working (W), heating (Q) and radiating (R). These transfer modes operate to move energy between the system and the surroundings. It is very important to recognize that such energy transfers affect *both* the system and the surroundings. Energy doesn't mysteriously appear or get lost.

1. Working (referred to as work by the physicists as if it is something different from energy) is the way in which energy is transferred between macroscopic (large enough to be seen) objects that exerts forces on one another. It is OK to calculate how much "work" one object does on another so long as you do not think that work is something an object stores.

2. Heating (referred to as heat by the chemists) is the way in which energy is transferred by the collisions of countless microscopic objects. Energy is always transferred from the "hotter" object (one in which the molecules have greater E_k) to a colder one (one in which the molecules have lower E_k). If all the molecules have the same mass, then the "hotter" ones are moving faster than the "colder" ones. It's OK to say that you heat an object – just not that the object stores heat.

3. Radiating is the process in which energy is transferred by the absorption or emission of photons (particles of light). A light bulb filament can be heated to the point that it glows; this is the emission of photons that carry energy away from the filament. You can be warmed by light from the sun as the photons transfer energy to you.

The relationship between energy storage and transfer is given by the 1st Law of Thermodynamics, $\Delta E = W + Q + R$. This is shown by the system schema below:



It shows that energy transferring into and out of the system affects the nature of the energy storage in the system. The 1st Law of Thermodynamics and the Law of Conservation of Energy state that the algebraic sum of these energy changes and transfers must add up to zero, accounting for all changes relative to the system.

Kinetic Molecular Theory (KMT)

This is one of the really important theories in chemistry. It accounts for the behavior of substances during all sorts of physical change. There are three key points:

1. Matter is made of tiny particles that are in constant random motion.
2. These particles exert long-range attractions and short-range repulsions on one another. Attractions bring about a reduction in the energy state (E_i) of the system; repulsions bring about an increase in the energy.

3. A hotter sample is one whose molecules are moving (on average) faster than the molecules in a colder sample.

Energy Reading Study Guide

Historical view:

Describe what early chemists meant by caloric

What is our more modern word for caloric? ___________

Our understanding of what causes changes to happen took two different paths that we eventually realized were the same. In paragraph 3 these are identified. Describe the two kinds of change scientists had studied

1.

2.

What two ideas about energy were lost when the caloric idea was abandoned?

The _____________________ and ____________________ of energy

Summarize the three principles guiding our modern view of energy

1.

2.

3.

Information is used as a metaphor to describe what energy is like. Describe the ways information is like energy, according to your reading.

Money accounts is another metaphor that can help us understand energy storage and transfer. Describe the ways money accounts are like energy.

We will be discussing three storage "accounts" to understand the changes we see in chemistry. State their names and describe how energy is stored in these three storage modes (how would you recognize that energy is present in these accounts in a system of matter?).

1.

2.

3.

We can transfer energy by three mechanisms. Identify the three and state how you would recognize each one in a system of matter.

1.

2.

3.

Unit 3 Lab: Icy Hot

Lab Write-up – Things to include

Write up the Questions, Procedure and data as usual.

<u>During the Evaluation and conclusion sections include the following items.</u>

Divide your heating curve into three regions; label each region:
(A) a low temperature plateau
(B) a region of temperature change
(C) a high temperature plateau

The following questions should be answered at the end of the lab.

1. Did the system in this lab involve a chemical change? Explain. Did the system absorb or release energy? Explain.

2. For *each* region on your graph,
   a. describe how the energy supplied by the burner was stored by the system (E_{th} or E_i)
   b. state what phases were present
   c. draw a model at the molecular level that shows how the water molecules were behaving.

3. How would increasing the rate of heating by using a higher hot plate setting affect the shape of the curve?

Unit 3 Lab: Freezing Lauric Acid

Procedure

1. Fill a 400 mL beaker 2/3 full of cool water. Put on your goggles!

2. Launch Logger Pro. Go to [Experiment] → [Data collection]. Change the length of the experiment to 20 minutes and the sampling rate to 2 readings/second.

3. Obtain a tube filled with molten lauric acid[3]. Clamp the tube to the ring stand, insert the temperature sensor into the tube of molten lauric acid and wait until the reading stabilizes; make sure the initial temperature is at least 60˚C. Press the [Collect] button and lower the tube into the beaker of cool water.

4. For the first few minutes, gently move the probe up and down in the lauric acid between readings. When the acid begins to stiffen, leave the probe in the middle of the sample.

5. Allow Logger Pro to collect data until it reaches the end of the time interval. Print the page and quit the program.

6. Disconnect the temperature probe and transfer the test tube of lauric acid with the embedded probe to the beaker of warm water. When the lauric acid melts to the point that the probe comes free, wipe the probe with a piece of paper towel and replace the probe at the lab station.

Lab Write-up

Divide your heating curve into three regions; label each region:
(A) a region of temperature change
(B) a temperature plateau
(C) a region of temperature change

The following questions should be answered at the end of your lab report.

1. Did the lauric acid undergo a chemical change? Explain.
   Did the system absorb or release energy? How do you know?

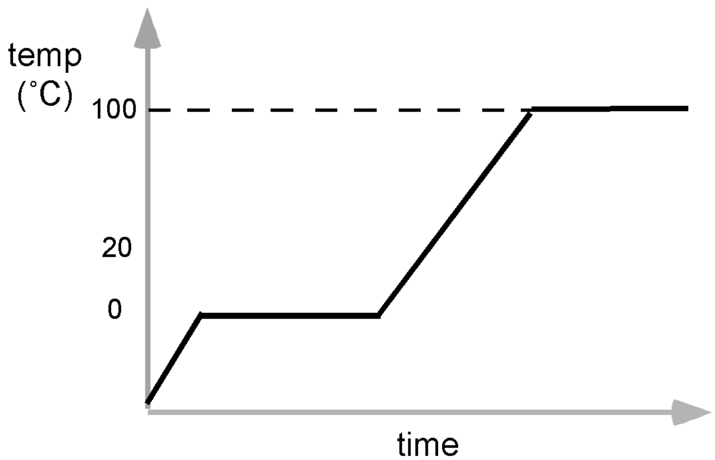
2. For each region on your graph,
   a. describe from what account the lauric acid transferred energy (E_{th} or E_i)
   b. state what phases were present
   c. draw a model at the molecular level that somehow shows how the lauric acid molecules were behaving.

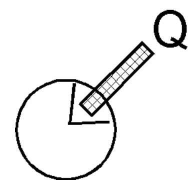
3. How would increasing the size of the sample affect the shape of the curve?

[3] Lauric acid is an organic compound found in candle wax. It is not a strong acid.

Chemistry – Unit 2 – Heating Problems

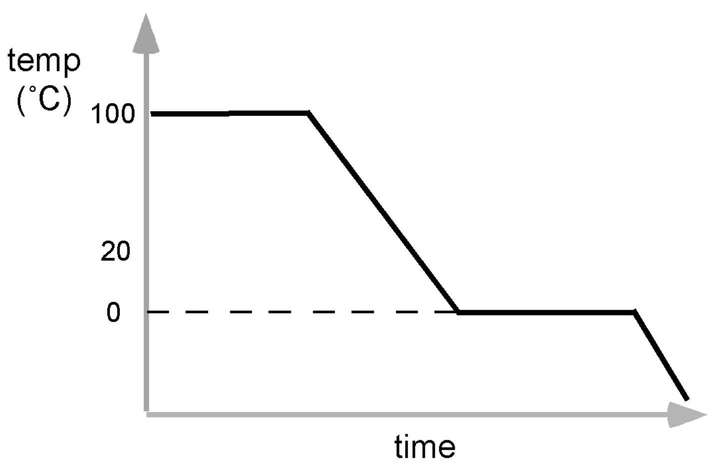
If you started with a sample of solid water well below the freezing point and supplied energy to it at a steady rate until it had partially boiled away, you would obtain a heating curve like the one below:

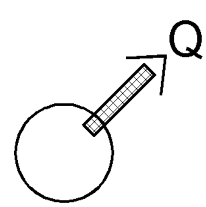




In our energy flow diagram we would show energy entering the entering the system via heating during this series of changes. changes. On the plateaus, the phase was changing and the the system was storing E_i. On the inclines, the temperature temperature was changing and the system stored E_k.

If we had started with boiling water and allowed it to cool until it had frozen completely and cooled to below 0°C, we would have obtain a graph like the one below:





In our energy flow diagram we would show energy leaving leaving the system via heating. On the plateaus, the system system was giving up E_i as the phase changed. On the declines, the temperature was changing and the system lost system lost E_k.

We are now interested in learning just *how much* energy is transferred during these changes. From experiment, we have learned that it takes 4.18 joules[4] to raise the temperature of 1 g of liquid water by 1 °C. This amount of energy is equivalent to one calorie. We can write this value as a factor $\frac{4.18J}{1g \cdot 1^{\circ}C}$. Suppose that we have a larger sample of liquid water, say 250 g. Clearly, it would take 250x as much energy to raise the temperature by one °C. In like manner, it would take 40x as much energy to raise the temperature by 40°C. We can show this in an equation: $Q = mc\Delta T$ where Q is the quantity of heat transferred, m represents the mass (in g), c is a property of liquid water known as the heat capacity, and ΔT is the change in temperature. Using the values above, $Q = 250g \cdot \frac{4.18J}{g^{\circ}C} \cdot 40^{\circ}C = 41{,}800J$ or $41.8kJ$. We usually use kJ as the unit for our answers because the joule is a pretty small unit of energy.

We note from experiment that ice, $H_2O(s)$, warms more rapidly than liquid water. Its heat capacity is $\frac{2.1J}{g^{\circ}C}$. This means that only about half as much energy is required to raise the temperature of one gram of ice by one degree Celsius. Substances like metals have much lower heat capacities. You certainly have had experience with this fact if you have ever picked up a piece of metal that was lying in the sun. The radiant energy R, raised the temperature of the metal to an uncomfortably hot temperature.

We cannot use this relationship on the plateau portion of the heating (or cooling) curve because there the temperature is constant ($\Delta T = 0$). So we must use a different equation: $Q = m\Delta H_f$ when the substance is melting (or freezing) and $Q = m\Delta H_v$ when the substance is vaporizing (or condensing). Note that the quantity of energy is related to the mass of the substance times a property of that substance. For water, ΔH_f is 334 J/g, and ΔH_v is 2260 J/g. These values make sense when you consider that pulling apart molecules of liquid water until they become widely separated in a gas is more difficult than simply giving the solid water enough energy to allow the molecules to move freely past one another.

Calculations of energy changes on the plateaus are easy, but you have to make sure that you use the correct value of ΔH. To melt 50 g of ice requires $Q = 50\,g \cdot 334\,{}^{J}\!/_{g} = 16.7kJ$, but to vaporize that same quantity of water requires $Q = 50\,g \cdot 2260\,{}^{J}\!/_{g} = 113kJ$, a much greater amount.

[4] A joule is the SI unit of energy.

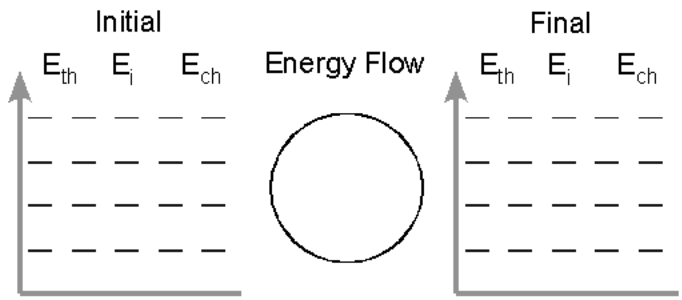
Name______________________________________

Date__________ Pd____

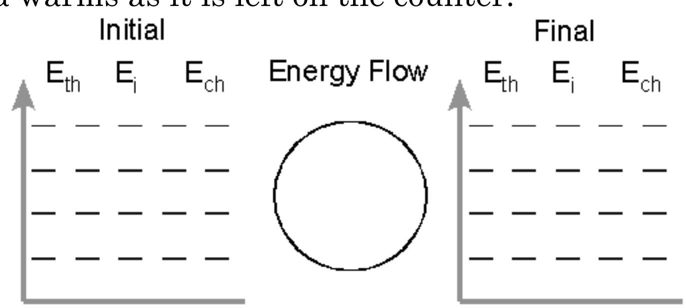
Unit 3 - Worksheet 1

For each of the situations described below, use an energy bar chart to represent the ways that energy is stored in the system and flows into or out of the system. Below each diagram describe how the arrangement and motion of the molecules change from the initial to the final state.

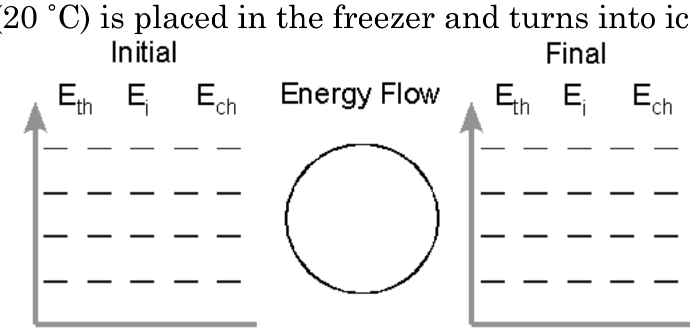
1. A cup of hot coffee cools as it sits on the table.



2. A can of cold soda warms as it is left on the counter.

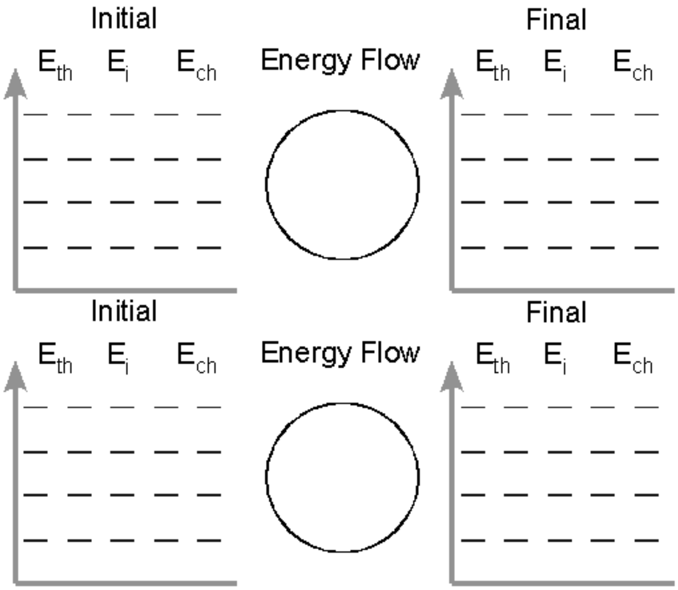


3. A tray of water (20 ˚C) is placed in the freezer and turns into ice cubes (- 8 ˚C)



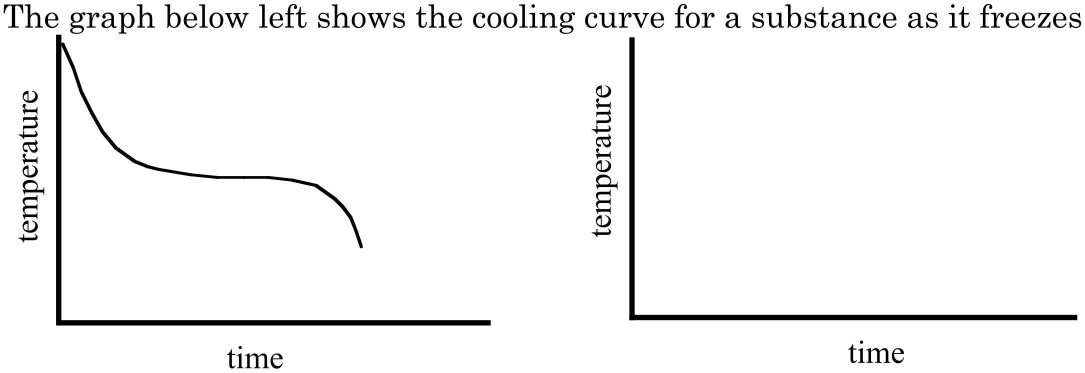
4. Where does the energy that leaves the system in #3 go? How does this energy transfer affect the room temperature in the kitchen? Do you have any experience that supports your answer?

5. One of the ice cubes described in #3 is placed in a glass of room temperature (25 ˚C) soft drink.
Do separate bar charts for the ice cube and the soft drink.



Describe how the arrangement and the motion of the molecules in each system change from the initial to the final state.

6. The graph below left shows the cooling curve for a substance as it freezes.



a. On the graph at right sketch the cooling curve for a larger sample of the same substance.

b. Label which phase (or phases) of the substance is present in each of the three portions of the cooling curve.

c. Describe the arrangement and motion of the molecules during each portion of the graph.

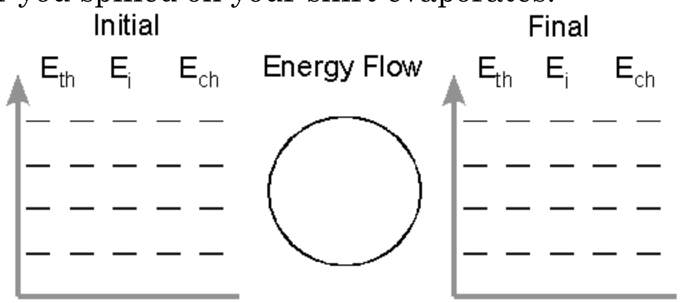
Name____________________________________

Date__________ Pd____

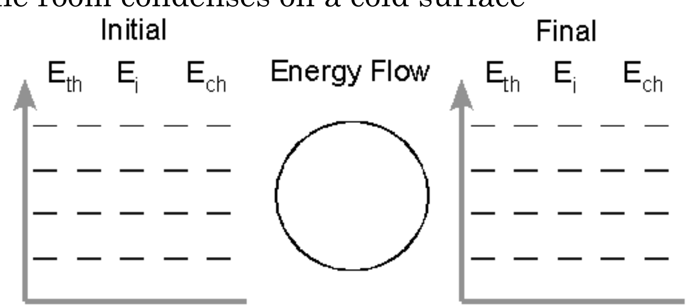
Unit 3 - Worksheet 2

For each of the situations described below, use an energy bar chart to represent the ways that energy is stored in the system and flows into or out of the system. Below each diagram describe how the arrangement and motion of the molecules change from the initial to the final state.

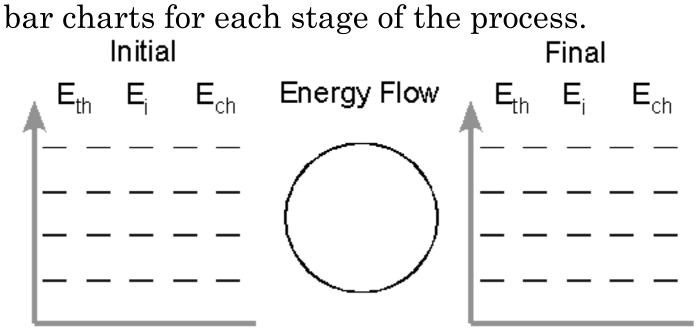
1. Some of the water you spilled on your shirt evaporates.

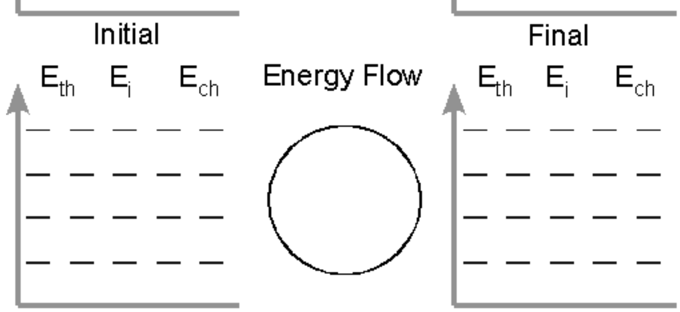


2. Water vapor in the room condenses on a cold surface



3. A pan of water (25˚C) is heated to boiling and some of the water is boiled away. Do separate energy bar charts for each stage of the process.





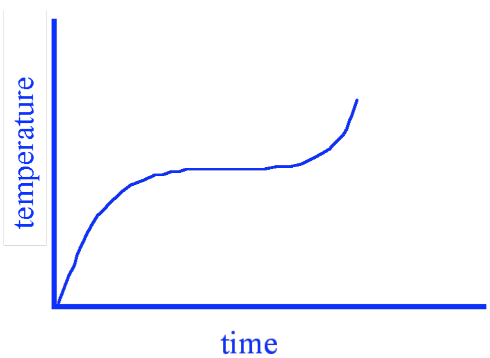
4. During boiling, bubbles appear in the liquid water. In the boxes below represent the arrangement of molecules inside the liquid water and inside a bubble.

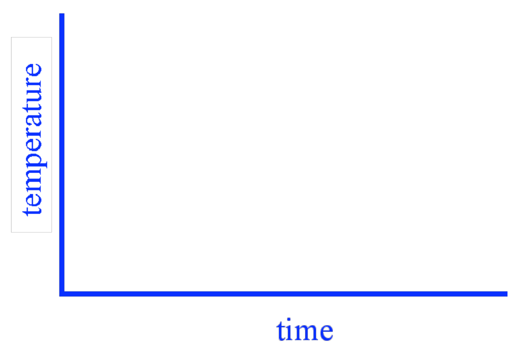
liquid water   bubble

What is inside the bubble? Why do you think so?

5. Suppose the burner under the pan of boiling water is turned to a higher setting. How will this affect the temperature of the water in the pan? Explain.

6. The graph below left represents the heating curve for a liquid heated from room temperature to a temperature above its boiling point.





a. Sketch the heating curve for a larger sample of the same liquid.

b. Label which phase (or phases) of the substance is present in each of the three portions of the heating curve.

c. Describe the arrangement and motion of the molecules during each portion of the graph.

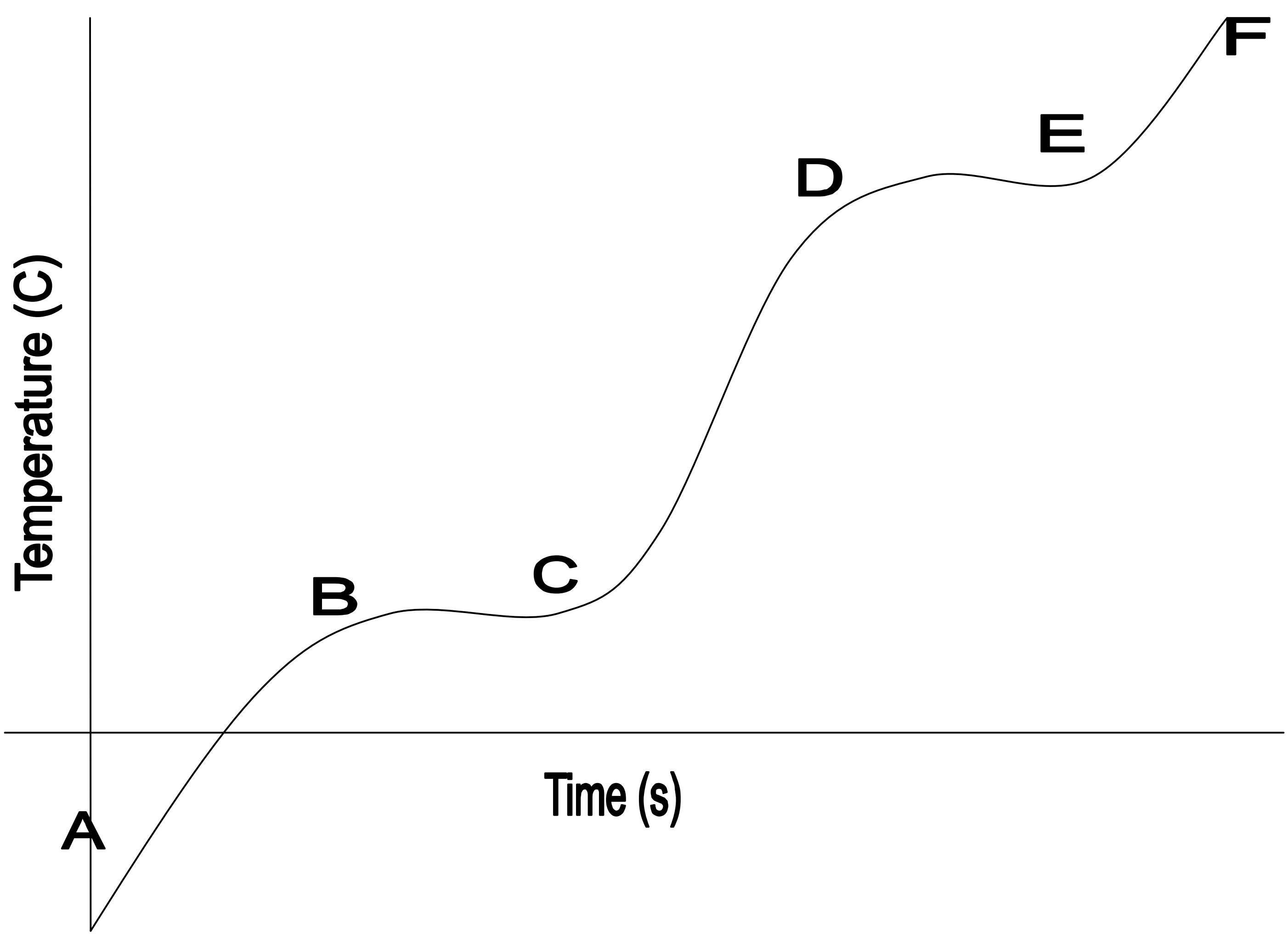
Representing Phase Changes

I. Temperature-Time Graphs:

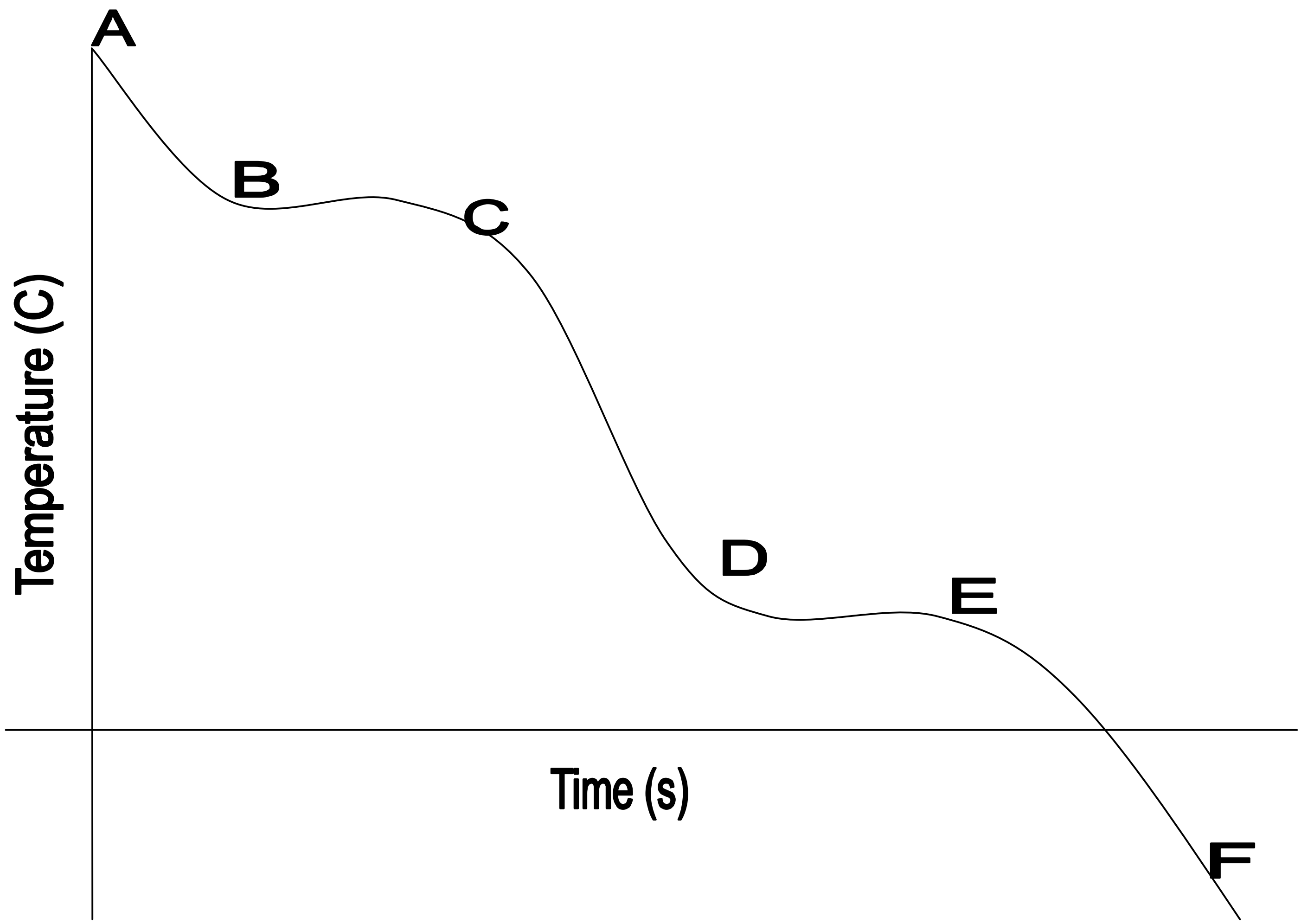
The temperature of a substance as it is steadily heated or cooled is shown in Graphs 1 and 2 below. Show the changes in matter and energy by adding these to each graph:

1. **At** each labeled point (A, B, C…) on the graphs draw
   a. a particle diagram to show the arrangement of matter particles
   b. a qualitative energy bar graph
2. **Between** each pair of labeled points (A-B, B-C, C-D…), write or draw
   a. the state(s) of matter that are present
   b. the change that is occurring (ex: temperature change, melting, condensing…)
   c. an energy flow diagram showing how the energy of the system is changing (is it by working, heating, or radiating? is being energy transferred into or out of the system?)

1. Temperature - Time During a State Change



2. Temperature - Time During a State Change



II. Explain the differences and/or similarities between the terms in each set below:

1. Temperature, Energy, “Heat”
2. Kinetic Energy, Interaction Energy
3. Solid, Liquid, Gas
4. Melting, Freezing
5. Evaporating, Condensing

Name ____________________________________

Date ________________ Pd ___

Unit 3 Worksheet 3 – Quantitative Energy Problems

Energy constants (H_2O)

334 J/g	Heat of fusion (melting or freezing) H_f
2260 J/g	Heat of vaporization (evaporating or condensing) H_v
2.1 J/g˚C	Heat capacity (c) of solid water
4.18 J/g˚C	Heat capacity (c) of liquid water

For each of the problems sketch a warming or cooling curve to help you decide which equation(s) to use to solve the problem. Keep a reasonable number of sig figs in your answers.

1. A cup of coffee (140 g) cools from 75˚C down to comfortable room temperature 20.˚C. How much energy does it release to the surroundings?

2. Suppose during volleyball practice, you lost 2.0 lbs of water due to sweating. If all of this water evaporated, how much energy did the water absorb from your body? Express your answer in kJ. 2.2 lbs = 1.0 kg

3. Suppose that during the Icy Hot lab that 65 kJ of energy were transferred to 450 g of water at 20˚C. What would have been the final temperature of the water?

4. The heat capacity of solid iron is 0.447 J/g˚C. If the same quantity of energy as in #3 were transferred to a 450 g chunk of iron at 20.˚C, what would be the final temperature?

5. Suppose a bag full of ice (450 g) at 0.0 ˚C sits on the counter and begins to melt to liquid water. How much energy must be absorbed by the ice if 2/3 of it melted?

6. A serving of Cheez-Its releases 130 kcal (1 kcal = 4.18 kJ) when digested by your body. If this same amount of energy were transferred to 2.5 kg of water at 27˚C, what would the final temperature be?

7. If this same quantity of energy were transferred to 2.5 kg of water at its boiling pt, what fraction of the water would be vaporized?

Name ______________________________

Date _______________ Pd ___

Unit 3 Worksheet 4 – Quantitative Energy Problems
Part 2

Energy constants (H_2O)

334 J/g	Heat of fusion (melting or freezing) H_f
2260 J/g	Heat of vaporization (evaporating or condensing) H_v
2.1 J/g˚C	Heat capacity (c) of solid water
4.18 J/g˚C	Heat capacity (c) of liquid water

For each of the problems sketch a warming or cooling curve to help you decide which equation(s) to use to solve the problem. Keep a reasonable number of sig figs in your answers.

1. How much energy must be absorbed by a 150 g sample of ice at 0.0 ˚C that melts and then warms to 25.0˚C?

2. Suppose in the Icy Hot lab that the burner transfers 325 kJ of energy to 450 g of liquid water at 20.˚C. What mass of the water would be boiled away?

3. A 12oz can of soft drink (assume m = 340 g) at 25˚C is placed in a freezer where the temperature is – 12 ˚C. How much energy must be removed from the soft drink for it to reach this temperature?

4. 65.0 kilojoules of energy are added to 150 g of ice at 0.0˚C. What is the final temperature of the water?

5. 250 kJ of energy are removed from a 4.00×10^2 g sample of water at 60˚C. Will the sample of water completely freeze? Explain.

6. An ice cube tray full of ice (235g) at –7.0˚C is allowed to warm up to room temperature (22˚C). How much energy must be absorbed by the contents of the tray in order for this to happen?

7. If this same quantity of energy were removed from 40.0 g of water vapor at 100˚C, what would be the final temperature of the water?

Name ______________________________

Date ________________ Pd ___

Unit 3 Worksheet 5 – Quantitative Energy Problems
Part 3

(Answers are in the parentheses)

1) If 100 g of aluminum and 100 g of iron each absorb the same amount of heat will they show equal amounts of temperature change? If so, explain why. If not, state which one will have the greater change and explain why.

2) 2.0 kg of mercury are heated from 0.0˚C to 100.0˚C. How much heat was added to the mercury during the process? *(2.8×10^4 kJ)*

3) In question 2 you found the energy needed to heat 2.0 kg of mercury from 0 to 100˚C. How many kilograms of water could be heated from 0 to 100˚C using the same amount of energy? Why is the mass less than that of mercury?
(67 g)

4) (a) How many joules of energy are needed to convert 1.80 kg of acetone at -95.4˚C from solid to liquid (also at -95.4˚C)?
(ΔH = 177 kJ)
(b) How many joules of energy are released when converting 1.8 kg of acetone from gas to liquid to if the temperature stays a constant 56.2˚C? *(ΔH = -902 kJ)*

5) 288 g of Oxygen gas at 25.0˚C (room temp) is cooled to -210.0˚C. How much energy is released as the gas is cooled to a much colder liquid.
($C_{oxygen\ gas}$ = 0.918 J/g˚C) ($C_{oxygen\ liquid}$ = 1.67 J/g˚C) *(ΔH = -68040 kJ)*

6) 75.0 g of ethanol (grain alcohol) at 346 K is heated from until it completely turns to steam at 351.5 K. How much heat is required to heat and evaporate the ethanol?
(1060 kJ)

7. (a) How much heat is required to raise the temperature of a 500.0 g iron bar from 25.0 to 50.0˚C? *(5750 kJ)*
(b) The iron bar at 50.0˚C is dropped into 500.0 g of water that is at 25˚C. The iron will cool and the water will warm until they both arrive at the same temperature. At what temperature will the system settle?
HINT: Energy is conserved! Whatever heat the bar loses must be gained by the water – one half is exothermic and the other is endothermic. *(27.5˚C)*

Specfic Heat Capacities of Some Common Substances		
	Specific Heat Capacity (C)	
	J/(g˚C)	**Cal/(g˚C)**
Water	4.18	1.00
Grain alcohol	2.4	0.58
Ice	2.1	0.50
Steam	1.7	0.40
Chloroform	0.96	0.23
Aluminum	0.90	0.21
Glass	0.50	0.12
Iron	0.46	0.11
Silver	0.24	0.057
Mercury	0.14	0.033

Heats of Physical Change

Substance	**Formula**	**Freezing point (K)**	**H_{fus} (kJ/g)**	**Boiling point (K)**	**H_{vap} (kJ/g)**
Acetone	CH_3COCH_3	177.8	0.099	329.4	0.502
Ammonia	NH_3	195.3	0.332	239.7	1.376
Argon	Ar	83.8	0.030	87.3	0.163
Benzene	CsH_s	278.7	0.127	353.3	0.395
Ethanol	C_2H_5OH	158.7	0.100	351.5	0.946
Helium	He	3.5	0.005	4.2	0.020
Hydrogen	H_2	14.0	0.060	20.3	0.450
Methane	CH_4	90.7	0.059	111.7	0.513
Methanol	CH_3OH	175.5	0.099	337.2	1.103
Neon	Ne	24.5	0.016	27.1	0.088
Nitrogen	N_2	63.3	0.026	77.4	0.199
Oxygen	O_2	54.8	0.014	90.2	0.213
Water	H_2O	273.2	0.334	373.2	2.261

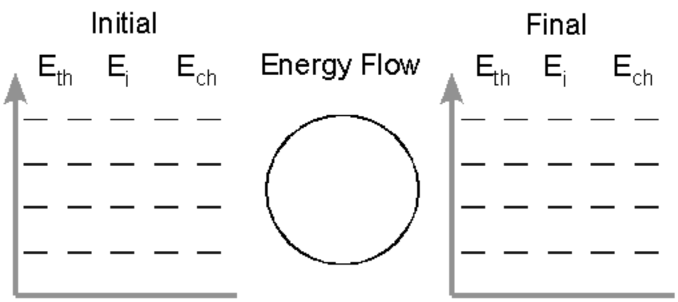
Chemistry – Unit 3 Review

To prepare to do well on the chapter 3 test, you should assemble your notes, the 4 worksheets and the quiz and review them, preferably in a small group where you can draw from each other's understanding. Here are the key points you should know.

Energy

Think of energy as a quantity that is always involved when there is a *change* in the state of matter. When a substance gets hotter or colder or changes phase, energy is either transferred into or out of the system. The two key ways energy is stored is **kinetic** (due to the motion of the particles) and **interaction** (due to attractions between the particles). Remember that attractions *lower* the energy state, so one must *add* energy to a system to pull particles apart. The three ways that energy is transferred is by heating (Q), working (W) and radiating (R); this course focuses on Q. You will be expected to be able to

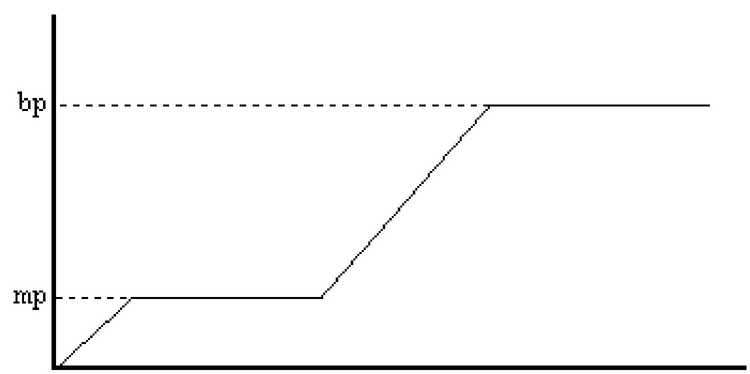
1. Draw energy bar graphs to account for energy storage and transfer in all sorts of changes. Make up a sample situation and sketch the bar graph. (review ws 1 and 2, quiz)



Kinetic Molecular Theory

This theory describes all matter as being composed of tiny particles in endless random motion. In a solid, the particles vibrate, but are locked into an orderly array. In a liquid, the particles are still touching but are free to move around past one another. In a gas, the particles are moving very rapidly and are widely separated.

When energy is transferred to a sample of matter, *either* the particles speed up (temperature increases) *or* they get pulled apart (phase change), but *not* both at the same time. This helps account for the shape of the warming curve you got in the Icy Hot lab.



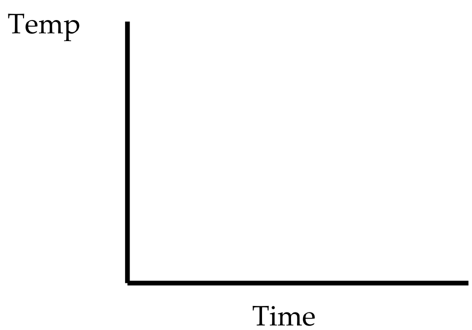
2. Label which phases are present in each portion of the curve on the previous page.

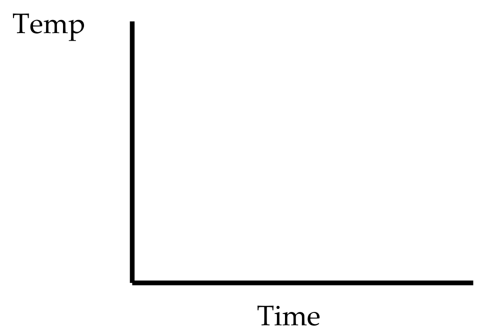
3. Label the sections in which the kinetic energy (E_k) of the sample is changing. Label the sections where the interaction energy (E_i) is changing.

Energy calculations

First, *before* you do any math, you should sketch a temperature-time curve so that you can focus on what changes are taking place.

4. On the graph below left sketch the curve that describes the following:
Initial state: 150 g solid water at –10 ˚C
Final state: 150 g liquid water at 0˚C





5. On the graph above right sketch the curve that describes the following:
Initial state: 200 g liquid water at 40 ˚C
Final state: half of the water has boiled away at 100˚C

When the temperature of a solid, liquid or gas is changing, energy, in the form of heat, Q, is involved. Rather than simply plug-n-chug values into an equation, reason out the quantity of Q from the value of c. For example, you know that 4.18 J is required to increase the temperature of each gram of liquid water by one Celsius degree. If you have more than one gram of water, or if the temperature changes by more than one degree, multiply by the appropriate amounts.

When the substance is undergoing a phase change (freezing or melting, condensing or evaporating), you know that you must use either H_f or H_v, both of which are factors that tell us the quantity of heat, Q involved for each gram. If more than one change is taking place, you must break the problem into steps. For these situations, temp-time graphs help you decide what is involved in each step (review ws 3).

6. Calculate the heat required to bring about the change in #4.

7. Calculate the heat required to bring about the change in #5.